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SOVIET DEVELOPMENTS IN INFORMATION PROCESSING
AND

MACHINE TRANSLATION

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SOVIET DEVELOPMENTS IN INFORMATION PROCESSING
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FOREWORD

This translation series presents information from Soviet literature on developments in the following fields in information processing and machine translation: organization, storage and retrieval of information; coding; programming; character and pattern recognition; logical design of information and translation machines; linguistic analysis with machine translation application; mathematical and applied linguistics; machine translation studies. The series is published as an aid to U. S. Government research.

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PROBLEMS OF WORD-ORDER
IN RUSSIAN-CHINESE MACHINE TRANSLATION AND THEIR SOLUTIONS⁽¹⁾

[Following is a translation of an article by Liu Yung-ch'uan in the Chinese-language periodical, Yu-yen Yen-chiu (Linguistics Research), No 4, September 1959, Peiping, pages 107-116.]

Before we begin the subject proper, let me first introduce the general picture of Russian-Chinese machine translation work. The present study was formally inaugurated in January of 1958. The methods it follows are the same as those used by the Institute for Precision Instruments and Calculator Technology, Academy of Sciences USSR. The material on which it is based is drawn principally from mathematics literature.

The Russian-Chinese machine translation system is composed of the following two separate stages: the analysis of the Russian sentence and the resynthesizing of the Chinese sentence. The purpose of the first stage is to analyze the Russian sentence to obtain the necessary information on the vocabulary and grammar, as a prerequisite to resynthesizing; the purpose of the second stage is to form Chinese sentences on the basis of the information obtained from the [above] analysis. Line graphs for the analysis of Russian sentences necessary for the machine translation of Russian into foreign languages have been produced by T. M. Nikolayev of the Institute of Precision Instruments and Calculator Technology, Academy of Sciences USSR. These line graphs, it seems, can be applied to our study once adjustments have been made to meet the requirements of Russian-Chinese machine translation.

There are the following two line graphs on the resynthesizing of the Chinese sentence: "Changing the Word Order" and "Translating Morphological Features". The first is the basic graph for the resynthesizing stages, and is fairly large and complicated. It processes the entire syntax of the sentence. The second is much smaller than the first, and deals with verbs performing the "predicate" function: morphological components of Russian verbs are rendered here by lexical elements in Chinese. For example, "Он написал⁽²⁾ статью", ("T'a hsieh-ch'eng-le lun-wen [He has written a paper]").

The foregoing is a general picture of Russian-Chinese machine translation. Now we return to the subject of our report.

The first part of the report will explain the concept of word order and its significance in machine translation. The second part will set forth in a concrete manner the problems of word order in Russian-Chinese machine translation and how they may be solved.

I. The Concept of Word Order and Its Significance in Machine Translation

Word order is in the realm of syntax, and hence should be thought of as the order of the units of sentence construction, whether these are composed of one word [tz'u] or of several, and should not be thought of as the order of the "independent words [tan-ko tz'u]" of lexicography and morphology.

When we speak of changing the word order, we mean the order of syntactical units (definitives, complements, and so forth) and not lexical or morphological units (nouns, adjectives, and so forth).

This concept of "word order" has an even broader meaning as applied to machine translation. It means not just the position of the components of a simple sentence, but the position of the even larger syntactical units (the clauses of a complex sentence) as well.

We can see from the above that this technical term "word order" is not very precise; it includes a large amount of assumption.

Word order has different functions in different languages. It is only a minor grammatical tool in some, but in others it has an exceptionally important or even major role.

The importance of word order is most clearly revealed in translating between two languages of entirely different type. It is a focal point of research work and is the deciding factor in the success or failure of machine translation.

To save time, we will say no more about the significance of machine translation. The second part of this report will naturally explain it more concretely.

II. The Solution of Word Order Problems in Russian-Chinese Machine Translation (MT)

Russian and Chinese are two different kinds of language. Russian is synthetic and inflected; Chinese is analytic -- its morphology is extremely undeveloped. Hence both have many features of construction not common to the other. And there are many obvious differences in word order as well.

It is often necessary, in translating from Russian to Chinese, to change the order of subjects, complements, parenthetical remarks, independent clauses, and dependent clauses, as well as that of definitives, appositives, and oblique-case nouns (which is done in many other MT systems). Almost all syntactical units, in other words, may change their order.

Now we will offer a few examples to show the differences between Russian and Chinese word order, and how complicated the processes of word order change in Russian-Chinese MT can be. (3)

1) "Какую пользу может принести этот прием?"

(shen-ma)(hao-ch'u) (k'o-yi) (tai-pai) (che-ko)(fang-fa)
[what] [benefit] [can] [bring] [this] [way]

Chinese translation: "Che-ko fang-fa k'o-yi tai-lai shen-ma hao-ch'u?"
[this] [way] [can] [bring] [what] [benefit]
[What benefit can this way bring?]

"
2) Какую из этих двух производных она символизирует?

(Naz-ko) (chih-chung-te) (che) (liang-ko) (tao-shu) (T'a) (tai-piao)
[Which] [of<-] [this] [two] [derivative] [it] [represent]

Chinese translation: "T'a tai-piao che liang-ko tao-shu
[It][represent][this] [two] [derivative]
chih-chung-te naz-ko?" [Which of these two derivatives (does) it represent
[of<-] [which]

3) "...приращение функции, имеющей производную в точке x,

(pien-liang) (han-shu) (chu-yu) (tao-shu (tsai) (tien) (x)
[expansion] [function][have] [derivative][at][point] [x]

может быть представлено в виде..."

(k'o-yi) (piao-tso)
[can] [represent as]

Chinese translation: "...tsai tien x chu-yu tao-shu (te)⁽⁴⁾ han-shu
[at][point][x][have] [derivative][(of/that <-)]
(te) pien-liang k'o-yi piao-tso..."
[function][(of/that <-)][expansion][can][represent as]
[(The) expansion of (the) function hav(ing) (its) derivative at point x
can (be represent(ed) as]

4) "Как цифровой код сообщения на русском языке преобразуется в
(ju-ho)(shu-ma)(hsin-hsi) (E) (wen) (pien-ch'eng) (shu-ma)
[How][number][information][Russ-][-ian/ese] [convert to][number]

цифровой код сообщения на китайском языке?"

(hsin-hsi) (han) (wen)
[information][chin-][-ian/ese]

Chinese translation: "E-wen hsin-hsi (te) shu-ma ju-ho
[Russian][information][(of/with/that <-)][number][How]
pien-ch'eng han-wen hsin-hsi (te) shu-ma?"
[convert to][Chinese][information][(of/with/that <-)] [number]
[How (are)(the) number(s) with information (in) Russian convert(ed)
to number(s) with information (in) Chinese]

5) "Производная этой функции равна, как мы знаем,

(tao-shu) (che-ko) (han-shu) (teng-yü) (cheng ju) (wo-men) (so-chih)
 [derivative] [this] [function] [equal] [as] [we] [know]

Chinese translation: "Cheng ju wo-men so-chih, che-ko han-shu
 [As] [we] [know] [this] [function]

{te} tao-shu teng-yü f'(x) q'(t)..."
 [of/with/that ←] [derivative] [equal]

[As we know, (the) derivative of this function equal(s)]

6) "Конечно, во всех случаях требуется оценка той погрешности
 (Tang-jan) (tsai) (yi-ch'ieh) (ch'ing-k'uang) (hsu-yao) (ku-chi) (na-ko)
 [Of course] [at/in] [all] [case] [must] [evaluate] [the]

о/Δ x/, которую мы допускаем, заменяя приращение функции dy
 (wu-ch'a) (o/Δ x/) (wo-men) (tsao-ch'eng) (tai-t'i) (pien-liang)
 [error] (o/Δ x/) [we] [created] [represent] [expansion]

(ее дифференциалом
 (han-shu) (wei-fen)
 [function] [differential]

Chinese translation: "Tang-jan, tsai yi-ch'ieh ch'ing-k'uang (tu)
 [Of course] [in] [all] [case] [(all)] (5)

hsu-yao ku-chi wo-men (tsai) (yung) wei-fen dy
 [must] [evaluate] [we] [(at/in)] [(use/with)] [differential] dy

tai-t'i han-shu Δ y (te) pien-liang shih
 [represent] [function] Δ y [of/with/that ←] [expansion] [when ←]

tsao-ch'eng (te) na-ko wu-ch'a o/Δ x/."
 [create] [(of/with/that ←)] [that] [error] o/Δ x/

[of course in every case (we) must evaluate the error o/Δ x/ create(d)
 when we represent (the) expansion of (the) function Δ y with (the)
 differential dy]

A line graph "Changing the Word Order" has been provided in the Russian-Chinese MT system to change the types of word order shown above. It is based on dictionaries (6) and on the information obtained in the analytical stage.

Also, it is composed of the following five interrelated secondary line graphs developed in order: "Definitives and Appositives," "Oblique-case nouns," "Subjects," "Complements," and "Dependent clauses." The first four change the order of sentence components in simple sentences and in the clauses of complex sentences; the last one, the order of dependent clauses in complex sentences.

Before analyzing these line graphs, we will first talk a bit about a few of the basic principles along which they are organized:

A. The first thing in changing word order is to decide upon the basic pivot around which word order changes will be made. This basic pivot is the predicate. The position of subject, complement, and some oblique-case nouns are all determined by the predicate. The pivot for definitives is their antecedent.

B. The order in which the secondary line graphs are arranged and the order of their steps are extremely important. Many mistakes will be made in translation if proper attention is not given to these orders. For example: "Какую из этих двух производных она символизирует?" ("Which of these two derivatives does it represent?"). If the processing of the direct complement is done before that of the indirect complement, there will be no place to the left of the indirect complement to put the word (какую) that it complements and explains.

To keep the work in order and to have a logical arrangement, all words having the characteristics of "special adverbial oblique case nouns" are processed in the secondary line graph "Definitives and Appositives"; words having the characteristics of "complements" or to be found in definitive groups, participial phrases, or gerundive phrases are processed in the appropriate secondary line graph. See below for details.

C. Related to the foregoing two points is this: definitives and their antecedents must be taken as a unit (a combination), and this applies equally to other interrelated syntactical units. The way to achieve this objective is: assign a common number to all words that are entered in the combination. If this is not done, it will result either in a distortion of the original, or else a meaningless jumble of words. For instance:

"...приращение функции, имеющей	производную в
(pien-liang) (han-shu) (chü-yu) (tao-shu) (tsai)	
[expansion] [function] [have] [derivative][at/in]	

точке	x"	
(tien) (x)	might be rendered	"han-shu (te) chü-yu
[point] [x]		[function][of/with/that←-)][have]

pien-liang-tien	tao-shu	tsai	(x)"
[expansion point]	[derivative][at/in]	[x]	

[The derivative of the expansion point of the function (that the function has) is at x?]

D. In changing the word order, it is necessary to rearrange the punctuation - - when translating Russian to Chinese, it is often necessary to add or to omit various marks of punctuation. This is always best done during the process of changing the word order. For example: "Производная этой функции равна, как мы знаем, $f'(x) \varphi'(t)$" ("As we know, the derivative of this

function equals $f'(x)\Phi'(t)...$). When changing the word order, the two following extra steps are performed in order to eliminate the comma before the parenthetical remark and incorporate the comma after it:

- (1) Drop the comma to the left of the word (the parenthetical remark).
- (2) Give the comma to the right the same number as the word.

E. It is often necessary during the process of changing the word order, to add certain words to translate the morphological elements of the Russian -- when translating Russian to Chinese, imperfect definitives formed of second-case nouns should be moved in front of their antecedents, and the character "te" then inserted between definitive and antecedent, all to express the idea of possession indicated by the genitive. For example: the word: "дифференциал (wei-fen) функции (han-shu)" is processed in the following manner:

- | | |
|----------|--|
| 1/2, 12/ | See if there is a word in the clause having the characteristics of "verbal noun"; |
| 5/6, 3/ | See if there is to the right of it a word with the characteristics of "second-case noun acting as <u>imperfect definitive</u> "; |
| 8/9, 11/ | See if there is to the left of it a word with the characteristics of a "noun"; |
| 9/0, 0/ | Move it in front of the word you find, and give it the number of that word, then add "te" immediately before the word you found. |

Then you will get: "han-shu (te) wei-fen" [(the) derivative of (the) [function][of][derivative] function].

It can be seen from points D and E above that this line graph can be used to rearrange the punctuation and translate some features of Russian morphology as well as to change the word order.

Now we will take up separately each of the secondary line graphs in this "Changing Word Order" line graph.

In the secondary line graph "Definitives and Appositives", the processing of "Appositives" is dealt with first, and then "Definitives"

A decided majority of the appositives in the literature of mathematics are formulas. Formulas following nouns are generally appositives. Only a small number are definitives.⁽⁷⁾ The appositives are left where they are, but the definitives must be moved in front of their antecedent.

Distinguishing between the appositives and the definitives presents no great problem; positive results can be had by observing the word or words immediately before. If a formula follows a word of the точка, переменная, функция, приращение, величина, производная, дифференциал, катет, угол,

треугольник type, it is an appositive. Otherwise, it is a definitive.
For example:

- 1) "В прямоугольном треугольнике МТР катет ТР равен другому МР..."
"In the right angle МТР, side ТР equals side МР...."

- 2) "..... в частности, производная порядка n

$$y^{(n)} = n! a$$

есть даже многочлен степени 0, т.е. постоянное число....."
"especially an n th order derivative

$$y^{(n)} = n! a$$

even a 0 degree polynomial, in other words a constant....."

The "Definitives" part of this graph deals with the processing of words having the characteristics of the following: "Special Adverbial Oblique Case Nouns", "Perfect Definitives", "Imperfect Definitives in the Form of Infinitives", "Imperfect Definitives in the form of Second-Case Nouns", "Imperfect Definitives in the Form of Prepositional Phrases", "Independent Definitives in the Form of Postpositional Adjectives", and "Participial Phrases".

Of the foregoing modifiers only one, the "Perfect Definitive", comes before its antecedent in Russian (aside from a few cases of inverted order), all the rest come after. Combinations of the type (разного рода вопросы) will be considered separately.

As everyone knows, however, in Chinese all modifiers precede the word modified. Hence the post-positional definitives of the Russian must be moved in front of their antecedents. If there are definitives both before and after the antecedent, the post-positional definitive is generally moved ahead of the pre-positional one. For example:

- 1) "Цифровой код сообщения на русском языке"
(shu-ma) (hsin-hsi) (E) (wen)
[number] [information] [Russ-] [-ian]

"E-wen (te) hsin-hsi (te) shu-ma"
[Numbers with information in Russian]

- 2) "Приращение функции, имеющей производную в точке x "
(pien-liang) (han-shu) (chü-yu) (tao-shu) (Tsai) (tien) (x)
[expansion] [function] [have] [derivative] [at] [point] [x]

"Tsai tien x chü-yu tao-shu (te) han-shu (te) pien-liang"
[at][point][x][have][derivative][that] [function][of][expansion]

[The expansion of the function having its derivative at point x]

It should be pointed out that words having the characteristics of "special adverbial oblique case nouns", words having the characteristics of "direct complement" and following verbal noun definitive, and words having the features of "direct complement", "indirect complement" or "oblique case nouns" which appear in participial phrases must all be processed on this secondary graph. Faulty translation will result from failure to process them here. For example:

- 1) "Выражение (4) для производной служит прежде всего очень удобным обозначением ее...."
 (shih) (4) (dui-yü... (tao-shu) lai shuo) (shih)
 [expression][4][as far as(derivative) is concerned] [is]
 удобн^{ым} обозначением ее...."
 (shou) (hsien) (hen) (fang-pien-te) (chi-hao) (t'a-te)
 [of all][first][very] [convenient] [sign] [for it]
 "Shih (4) dui-yü tao-shu lai shuo shou-hsien shih t'a-te hen fang-
 [The expression 4 is first of all a very convenient designation
 pien-te chi-hao..."
 for the derivative]
- 2) "Дело защиты мира священо."
 (shih-yeh) (Pao-wei) (ho-p'ing) (shen-ching-te)
 [cause [preserving][peace] [sacred]
 "Pao-wei ho-p'ing (te) shih-yeh (shih) shen-ching-te"
 [preserving][peace][that/of/for ←][cause][is] [sacred]
 [The cause of preserving peace is sacred]
- 3) "погрешность, вводимая такой заменой"
 (wu-ch'a) (yin-ch'i) (che-chung) (tai-t'u)
 [error] [introduce] [this] [substitut(ion)]
 "(Yu) che-chung tai-t'i yin-ch'i (te) wu-ch'a."
 [by][this] [substitut(ion)][introduce][that/of/for/by ←][error]
 [The error introduced by this substitution]

At the same time we must also explain that words with the above characteristics are not processed on any other secondary graph once they are processed on this one.

The secondary graph for oblique-case nouns applies to words with the features of "adverbial oblique-case noun", "oblique-case noun plus fifth-case noun", "oblique-case noun with preposition", "parenthetical expressions" and "gerundive phrase".

It should be specially noted here that any kind of oblique-case noun appearing after the predicate or after any word of a verbal nature (predicate adjective, predicate adverb, etc) in Russian mathematics literature is in the absolute majority of cases moved before such predicate or verbal word when translated into Chinese. For example:

- 1) "Функция у дифференцируема в точке х."
 "Han-shu y tsai tien x shih k'o-wei-te"
 [Function][y][at][point][x][is][differentiable]
- 2) "Функция, имеющая производную в точке х"
 "Tsai tien x chu-yu tao-shu te han-shu"
 [at][point][x][have] [derivative][of <][function]

It must be explained that whenever this secondary graph is applied to gerundive phrases, it applies alike to the direct and indirect complements in the gerundive phrase. Words processed by this secondary graph are not thereafter processed again by any secondary graph below.

Now we come to the secondary graph for "subjects", This is applied to words with the characteristics of subjects, and moves some subjects coming after the predicate to in front of the predicate. Subjects coming after the predicate should be moved before the predicate if there are no predicate adverbs or verbs like *иметься, существовать, требоваться* preceding, and no relative pronouns like *который* following.

This graph is simpler, for the reason that first of all in Russian and Chinese, especially in math literature, the subject generally comes before the predicate; secondly, that in the process of translation the sentence components may with a certain amount of discretion be changed, that is to say, the subject in Russian is not always translated as the subject in Chinese. For example:

- 1) "Во всех случаях требуется оценка погрешности",
 "Tsai yi-ch'ieh ch'ing-k'uang tou hsu-yao ku-chi wu-ch'a"
 [In all cases the error must be evaluated;
- 2) "Трудно решить эту задачу",
 "Hen nan chieh-ch'ieh che-ko wen-t'i" [It is very difficult to solve this problem].

The subject *оценка* of the first sentence becomes part of the predicate when translated into Chinese, and the subject of the second, *решить* becomes a predicate pure and simple.

The secondary line graph for "complements" processes first indirect complements and then direct complements. The processing of the indirect complements is conducted in the following order: indirect complement plus second case, then indirect complement plus third case, then indirect complement plus fourth case (with prepositions), then indirect complement plus fifth case, and finally indirect complement plus sixth case.

It is common for the sentence components to be changed when translating complements. This phenomenon is often accompanied by a change in word order. For example:

- 1) "Я пишу карандашом", "Wo (yung) ch'ien-pi hsieh-tzu";
 (Wo)(hsieh-tzu)(ch'ien-pi),[I][(use/with)][pencil] [write]
- 2) "Я занимаюсь машинным переводом".
 "(Wo) (yen-chiu) (chi-ch'i) (fan-yi)
 "Wo yen-chiu chi-ch'i fan-yi."
 [I] [study] [machine] [translation]

In the first case, the indirect complement is called an "oblique-case noun of means of action," and is therefore moved in front of the predicate. In the second case, the indirect complement is called a "complement" (otherwise known as an "object"), and is therefore left in its original position. (Whether it is called an "oblique-case noun of means of action" or "complement" depends on the predicate). Verbs of the type заниматься are numbered as a special class in the dictionary.

Complements dealt with by previous secondary graphs are not processed again with this one.

The secondary graph for "Adverbial Clauses" is applied only to definitive adverbial clauses at the present stage. This is basically sufficient for translating math literature.

Work with this secondary graph is begun only after all work in the range of subordinate clause in the sentence has been completed. Unlike the other secondary graphs, this one is not used to work with anything under the range of subordinate clause, but works with the whole sentence. It is explained briefly below.

First of all, check whether the sentence contains words with the characteristics of relative pronoun, (such as words like который); if it does, then the graph work begins as follows: all words to the right of the relative pronoun, to the end of the clause, are given the same number as said relative pronoun, and a "te" is put at the end of the clause; a word having the characteristics of a "noun" is looked for to the left of the relative pronoun (its antecedent), and this (the word so found) is put after the relative pronoun (that is to say, after its clause). (Here, moving the definitive after its antecedent is more economical from a technical manipulation standpoint).

Now we will offer a few examples to explain how the word order is changed in simple and complex sentences.

1)	Какую	пользу	может	принести
Word number:	1	2	3	4
Part of speech of source:	(definitive)	(complement)	(predicate)	(predicate)
Meaning:	(shen-ma)	(hao-ch'u)	(k'o-yi)	(tai-lai)
	[What]	[benefit]	[can]	[bring]
	этот	прием	?	
	5	6	7	
	(che-ko)	(fang-fa)		
	[this]	[method]		

After the first secondary graph is applied, the sentence changes to:
 (9) "1 → 2 + 2 3 4 5 → 6 + 6 7". The second secondary graph is not

used, since there is nothing to which it applies. After the third is applied, the results are: "1→2 + 2 5→6 + 6 3 4 7". After the fourth is applied, we get: "5→6 + 6 3 4 1→2 + 2 7". Translation: "Che-ko fang-fa k'o-yi tai-lai shen-ma hao-ch'u?" [this] [method][can] [bring] [What] [benefit] ["What benefit can this method bring?"]

2)	Машина	сохраняет	ту	скорость	,
Word number:	1	2	3	4	5
Part of speech					
of source:	(subject)	(predicate)	(definitive)	(complement)	
Meaning:	(chi-ch'i)	(pao-ch'ih)	(na-chung)	(su-tu)	
	[machine]	[maintain]	[that]	[speed]	

какую	она	имеет	в	той	момент	,
6	7	8	9	10	11	12
(rel. pron.)	(subject)	(predicate)	(preposition)	(definitive)	(obl.-case noun)	
(t'a)	(chü-yu)	(tsai)	(na-ko)	(shih-k'o)		
[it]	[have]	[at]	[that]	[moment]		

After the first secondary graph is applied, the sentence becomes: "1 2 3→4 + 4 5 6 7 8 9 10→11 + 11 12". The result of the second secondary graph is: "1 2 3→4 + 4 5 6 7 9→11→8 + 10→11→8 + 11→8 + 8 12". The third and fourth bring no changes. With the fifth we get: "1 2 6 + 7→5 + 9→11→8→6 + 10→11→8→6 + 11→8→6 + 8→6 + te 3→4 + 4 12". Translation: "Chi-ch'i pao-ch'ih t'a tsai na'ko shih-k'o chü-yu te [Machine] [maintain] [it][at/in][that][moment][have][that/for ←] na-chung su-tu". ⁽¹⁰⁾ ["The machine maintains the speed it had at that moment"] [that] [speed]

3)	Конечно	,	во	всех	случаях
Word number:	1	2	3	4	5
Part of speech					
Of source:	(obl.-case n.)	(preposition)	(definitive)	(obl.-case n.)	
Meaning:	(tang-jan)	(tsai)	(yi-ch'ieh)	(ch'ing-k'uang)	
	[Of course]	[at/in]	[all]	[case]	

требуется	оценка	той	погрешности	о(Δ x)	, которую
(predicate)	(subject)	(definitive)	(complement)	(appositive)	(rel. pron.)
(hsü-yao)	(ku-chi)	(na-ko)	(wu-ch'a)		
[must]	[evaluate]	[that]	[error]		

мы	допускаем	, заменяя	приращение	функции	Δу
13	14	15	16	17	18
(subject)	(predicate)	(obl.-case n.)	(dir. comp.)	(definitive)	(appositive)
(wo-men)	(tsao-ch'eng)	(tai-t'i)	(pian-liang)	(han-shu)	
[we]	[create]	[replace]	[expansion]	[function]	

ee	дифференциалом	dy	.
20	21	22	23
(definitive)	(ind. comp.)	(appositive)	
	(wei-fen)		
	[differential]		

With the first secondary graph, the sentence becomes: "1 2 3 $\boxed{4 \rightarrow 5}$ + 5 6 7 $\boxed{8 \rightarrow 9}$ + 9 + $\boxed{10 \rightarrow 9}$ 11 12 13 14 15 16 $\boxed{18 \rightarrow 17}$ + $\boxed{19 \rightarrow 18 \rightarrow 17}$ + te + 17 $\boxed{20 \rightarrow 21}$ + 21 + $\boxed{22 \rightarrow 21}$ 23". After the second: "1 2 $\boxed{3 \rightarrow 5}$ + $\boxed{4 \rightarrow 5}$ + 5 6 7 $\boxed{8 \rightarrow 9}$ + 9 + $\boxed{10 \rightarrow 9}$ 11 12 13 + tsai + yung + $\boxed{20 \rightarrow 21 \rightarrow 16 \rightarrow 14}$ + $\boxed{21 \rightarrow 16 \rightarrow 14}$ + $\boxed{22 \rightarrow 21 \rightarrow 16 \rightarrow 14}$ + $\boxed{16 \rightarrow 14}$ + $\boxed{18 \rightarrow 17 \rightarrow 16 \rightarrow 14}$ + $\boxed{19 \rightarrow 18 \rightarrow 17 \rightarrow 16 \rightarrow 14}$ + te + $\boxed{17 \rightarrow 16 \rightarrow 14}$ - shih + 14 23". Graphs three and four bring no change. With five we get: "1 2 $\boxed{3 \rightarrow 5}$ + $\boxed{4 \rightarrow 5}$ + 5 6 7 12 + $\boxed{13 \rightarrow 12}$ + tsai + yung + $\boxed{20 \rightarrow 21 \rightarrow 16 \rightarrow 14 \rightarrow 12}$ + $\boxed{21 \rightarrow 16 \rightarrow 14 \rightarrow 12}$ + $\boxed{22 \rightarrow 21 \rightarrow 16 \rightarrow 14 \rightarrow 12}$ + $\boxed{16 \rightarrow 14 \rightarrow 12}$ + $\boxed{18 \rightarrow 17 \rightarrow 16 \rightarrow 14 \rightarrow 12}$ + $\boxed{19 \rightarrow 18 \rightarrow 17 \rightarrow 16 \rightarrow 14 \rightarrow 12}$ + te + $\boxed{17 \rightarrow 16 \rightarrow 14 \rightarrow 12}$ + shih + $\boxed{14 \rightarrow 12}$ + te $\boxed{8 \rightarrow 9}$ + 9 + $\boxed{10 \rightarrow 9}$ 23".

Translation: "Tang-jan, tsai yi-ch'ieh ch'ing-k'uang (tou) hsu-yao
[Of course][at/in][all] [case] [(all)][must]
ku-chi wo-men (tsai) (yung) wei-fen dy tai-t'i han-shu
[evaluate][we] [(at/in)][(with/use)][differential] [replace][function]
 Δy (te) pien-liang (shih) tsao-ch'eng (te) na-ko
[(that/of \leftarrow)] [expansion] [(when \leftarrow)] [create] [that/of \leftarrow] [that]
wu-ch'a o(Δx)". ["Of course, in all cases (or every case) (we) must
[error]
evaluate the error o(Δx) created when we replace the expansion of
function Δy with the differential dy"].

Finally, it should be pointed out that there are still a series of problems which at the present stage have not been solved. For example:

- 1) Дифференциалом функции называется главная линейная часть ее приращения.
- 2) Надо изучать историю и грамматику русского языка.

The difficulty in the first example is that after the word order is changed, we arrive at an unsatisfactory translation ("T'a-te pien-liang-te chu-yao hsien-hsing pu-fen [Its] [expansion of] [major] [linear] [part] chiao-tso han-shu-te wei-fen" ["The expansion of its major linear section [be called] [function] [of] [differential] is known as the differential of the function"]; after the change of word order the word "its" appears in front of its antecedent ("function").

In the second example the difficulty is that the definitive "русского языка [of the Russian language]" can either have one antecedent, "грамматику", or two, "историю" and "грамматику."

Other problems besides these in the translation of definitive adverbial clauses have yet to reach a satisfactory solution.

Even so, it can now be said that the word order problems in Russian-Chinese machine translation have in principle been solved. Of course the line graphs we now have will still have to undergo further changes and additions.

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Footnotes

1. This paper was originally a report made by the author at the Machine Translation Conference held in Moscow from 15 to 21 May 1958. Only in a few extreme places has it been changed at all in presenting it here, so as to preserve the original appearance.

2. The underlined words are the ones to which the examples particularly pertain.

3. Pedagogical examples are drawn from A.Я. Hsin-hsin's Concise Course in Pedagogical Analysis.

4. Words in parentheses here are those added in the process of translating the morphological components.

5. This word "tou" was added during the final (or good Chinese) stage.

6. The dictionary used in machine translation provides, besides a translation, a series of special characteristics, (such as to what part of speech a word belongs, which class, whether it is a verbal noun, whether it takes a particular case, etc.), providing information in Russian on advanced analysis and formation of the Chinese sentence.

7. For convenience in machine translation, some complements are considered definitives.

8. Unlike the usual division, we do not class the "independent definitives in the form of postpositional adjectives" and the "participial phrases" as "perfect definitives".

9. Numbers in blocks are the changed numbers resulting from processing, 1-→2 indicates that 1 is now 2.

10. Explanation: the number 5(representing the comma) was dropped in the process of applying secondary graph number five; the word was given no translation in the thesaurus, hence it does no harm to the translation even though it still remains after the processing.

11. Explanation: 1) numbers 11 and 15(representing commas) are dropped in processing; 2) the word "ee" has no translation here; 3) the word "tou" is added during the final (good Chinese) step.

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